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The Effect of Body Structure and Physical Potential on 10x50 Meter Front Crawl Swimming Skills in South Sulawesi Athletes

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ABSTRACT

This study aimed to analyze the contribution of body structure and physical potential to 10×50-meter front crawl swimming performance among South Sulawesi athletes. Swimming performance, particularly in repeated middle-distance efforts, is theoretically influenced by the interaction between anthropometric characteristics and biomotor capacities, which determine propulsion efficiency, drag reduction, and metabolic sustainability. A quantitative correlational design was employed involving 45 competitive swimmers selected through purposive sampling. Body structure variables were assessed using standardized anthropometric measurements, including height, limb length, and body mass indicators, while physical potential was evaluated through validated tests of muscular strength, power, speed, flexibility, and cardiorespiratory endurance. Performance was measured using a 10×50-meter front crawl protocol representing repeated sprint-endurance demands. Data were analyzed using Pearson correlation and multiple regression tests at a 95% confidence level ($\alpha = 0.05$). The results demonstrated a significant simultaneous relationship between body structure and physical potential with swimming performance ($R = 0.845$; $p < 0.05$; $F = 52.298$), with a coefficient of determination (R^2) of 0.714. This indicates that 71.4% of performance variance is explained by the combined contribution of morphological and physiological factors. Athletes with more favorable anthropometric profiles and higher physical capacity achieved faster and more consistent swimming times. These findings highlight the importance of integrating anthropometric assessment and biomotor development into evidence-based training programs to optimize middle-distance front crawl performance.

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A. Conception and design of the study;
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INTRODUCTION

Swimming is one of the most strategic sports in multi-event competitions due to the large number of medal opportunities offered across various distances and styles. In competitive contexts, swimming events range from sprint to middle- and long-distance races, each demanding specific physiological, biomechanical, and anthropometric adaptations (Santos et al., 2023; Morais et al., 2020). Among these, middle-distance front crawl events require a complex interaction between aerobic endurance, anaerobic power, neuromuscular coordination, and hydrodynamic efficiency (Seifert et al., 2018; Barbosa et al., 2019).

In Indonesia, particularly in South Sulawesi, swimming has shown developmental progress, evidenced by medal acquisition at national championships. However, performance indicators suggest that the region still struggles to compete with provinces from Java and other high-performance centers. Based on recent championship results, South Sulawesi ranked ninth nationally, securing only two gold, one silver, and one bronze medal. This outcome reflects a competitive gap and indicates that athlete development has not yet reached optimal performance standards. Performance in middle-distance front crawl swimming is strongly influenced by biomotor components including muscular strength, explosive power, speed, endurance, flexibility, and agility as well as anthropometric characteristics such as height, limb length, body mass, and body composition (De Souza Castro et al., 2023; Schreven et al., 2022). These factors determine propulsion efficiency, stroke mechanics, drag reduction, and overall metabolic economy (Toussaint & Truijens, 2018; Morais et al., 2020).

Observational data indicate that many South Sulawesi swimmers exhibit limitations in physical conditioning and body structure optimization, which may influence propulsion efficiency and endurance performance. The interaction between body structure and physiological capacity is critical because hydrodynamic resistance in water is directly influenced by body dimensions and technical execution (Barbosa et al., 2019). Therefore, the central research problem lies in understanding whether suboptimal competitive outcomes are associated with insufficient integration of anthropometric and biomotor profiles in athlete development.

Recent literature emphasizes that swimming performance is multifactorial and determined by biomechanical efficiency, metabolic capacity, and anthropometric suitability (Morais et al., 2020; Santos et al., 2023). Studies demonstrate that elite swimmers possess superior upper limb strength and explosive power, which significantly correlate with sprint and middle-distance performance (Schreven et al., 2022). Additionally, aerobic capacity (VO_2max) and lactate threshold are decisive determinants of sustained performance in repeated swimming bouts (Hellard et al., 2019; Zacca et al., 2020).

Anthropometric characteristics also play a substantial role. Taller swimmers with longer upper limbs tend to generate greater propulsion force and stroke length, leading to improved swimming economy (Geladas et al., 2017; Nikolaidis et al., 2018). Body mass distribution and lean muscle mass are linked to enhanced force production and reduced drag (De Souza Castro et al., 2023). Moreover, stroke frequency and stroke length balance are biomechanical indicators strongly associated with performance outcomes (Seifert et al., 2018; Barbosa et al., 2019).

In middle-distance contexts, the ability to sustain repeated high-intensity efforts—such as in a 10×50-meter endurance protocol—requires efficient anaerobic recovery and aerobic stabilization (Zacca et al., 2020). Research suggests that swimmers with superior anaerobic power and muscular endurance demonstrate better consistency across repeated sprint sets (Santos et al., 2023). From a training perspective, periodized programs integrating strength training, power development, and technical refinement have shown significant improvements in performance metrics (Crowley et al., 2017; Suchomel et al., 2018). Contemporary models advocate for individualized training based on physiological profiling and anthropometric assessment to maximize adaptation (de Alencar Matos et al., 2025).

Biomechanically, swimming efficiency depends on minimizing drag while maximizing propulsive force, which requires coordination between neuromuscular activation and structural leverage (Toussaint & Truijens, 2018). Therefore, performance is not solely determined by technical skills but by the synergy between body dimensions and physiological readiness (Pratama et al., 2024). Collectively, these findings indicate that elite swimming performance emerges from the integration of biomotor capabilities and anthropometric optimization, rather than isolated variables. Despite extensive international literature examining either biomotor or anthropometric determinants of swimming performance, few studies have simultaneously analyzed both dimensions within a repeated middle-distance protocol such as the 10×50-meter front crawl test. Most prior investigations focus on single-distance sprint events (25 m or 50 m) or long-distance endurance races (Nikolaidis et al., 2018; Schreven et al., 2022).

Additionally, research conducted within Indonesian or regional athlete populations remains limited. There is a scarcity of empirical data specifically addressing swimmers in South Sulawesi, particularly regarding how body structure interacts with physical potential in determining repeated sprint-endurance performance. This limitation is critical because regional athlete characteristics may differ due to genetic, nutritional, and developmental factors (Geladas et al., 2017). Furthermore, previous studies often treat anthropometric and physiological variables independently, without analyzing their combined predictive contribution to performance outcomes (De Souza Castro et al., 2023). However, swimming biomechanics theory emphasizes that propulsion efficiency is determined by the interaction between force production and structural leverage (Toussaint & Truijens, 2018). Thus, separating these variables may overlook important synergistic effects.

Another gap lies in practical application. While research recommends individualized profiling, there is limited empirical evidence translating these profiles into middle-distance endurance evaluation frameworks suitable for regional training programs (de Alencar Matos et al., 2025). Therefore, there is a need for integrative research that bridges theoretical biomechanics with applied athlete development in a regional context. Based on the identified gaps, this study aims to analyze the relationship between body structure (anthropometric characteristics) and physical potential (biomotor components) in relation to 10×50-meter front crawl swimming performance among South Sulawesi athletes. Specifically, this research examines the combined contribution of strength, speed, endurance, flexibility, and anthropometric variables to repeated middle-distance performance outcomes.

The novelty of this study lies in three main aspects. First, it integrates anthropometric and biomotor variables simultaneously within a repeated endurance protocol (10×50 m), which differs from prior research focusing on single sprint evaluations. Second, it provides empirical data specific to South Sulawesi swimmers, thereby contributing to regional athlete profiling and contextualized sports science development. Third, it emphasizes the synergistic interaction between structural leverage and physiological capacity as predictors of propulsion efficiency and performance sustainability.

By identifying dominant determinants influencing performance, this research is expected to contribute to evidence-based training design, particularly in optimizing strength-endurance integration and anthropometric adaptation strategies. The findings may serve as a scientific foundation for more targeted and data-driven coaching programs in middle-distance swimming events. Ultimately, this study advances swimming coaching science by reinforcing the principle that performance excellence is not merely a product of technical mastery but the outcome of harmonized physiological readiness and anthropometric optimization within a biomechanical framework.

METHODS

This study used a quantitative approach with a correlational design to analyze the influence of body structure (anthropometric profile) and physical potential (biomotor abilities) on 10×50-meter freestyle swimming skills in South Sulawesi athletes. The correlational design was chosen because it is effective in identifying simultaneous relationships between physiological and morphological variables on sports performance without treatment manipulation (Morais et al., 2020; Santos et al., 2023). This approach is also relevant in multifactorial predictive studies of swimming performance (Barbosa et al., 2019; Zacca et al., 2020).

The study population consisted of 120 South Sulawesi swimmers actively registered in regional coaching programs. A sample of 45 athletes was selected using purposive sampling with the following inclusion criteria: (1) active athletes with at least one year of systematic training, (2) participation in regional/national competitions, and (3) no musculoskeletal injuries in the past three months. This sample size meets the recommendations for multivariate regression analysis in sports performance studies (Nikolaidis et al., 2018; de Alencar Matos et al., 2025).

Body structure variables were measured using anthropometric tests, including height, arm length, leg length, chest circumference, thigh circumference, and body weight. These parameters were chosen because they have been shown to influence stroke length, propulsion efficiency, and drag reduction in water (Geladas et al., 2017; De Souza Castro et al., 2023). Measurements were conducted in accordance with International Society for the Advancement of Kinanthropometry (ISAK) standards to ensure data reliability and validity.

Physical potential was measured through several key biomotor components that have been empirically correlated with middle-distance swimming performance. Arm muscle strength was measured using a modified leg dynamometer for the upper extremities, as arm propulsive strength is a major determinant of propulsive force in the front crawl (Schreven et al., 2022). Speed was assessed using a 60-yard dash test as an indicator of neuromuscular acceleration capacity (Suchomel et al., 2018). Explosive power was measured using a vertical jump test to represent muscle power capacity contributing to the start and turn phases (Crowley et al., 2017). Cardiorespiratory endurance was measured using a VO_2max estimation test, given that aerobic capacity plays a crucial role in maintaining performance in repeated sprint swimming (Zacca et al., 2020). Ankle flexibility was measured because ankle mobility influences plantar flexion angle and kick efficiency (Seifert et al., 2018).

Swimming performance was measured using a 10×50-meter freestyle test with controlled rest intervals. This protocol was chosen to represent the combination of anaerobic capacity and aerobic stabilization required in middle-distance events (Santos et al., 2023). Total time and consistency between repetitions were recorded using an electronic timing system to improve measurement accuracy.

Data collection procedures included: (1) technical explanation and informed consent, (2) a standard 10–15-minute warm-up, (3) anthropometric and biomotor tests,

(4) swimming tests, and (5) cool-down. All tests were conducted under controlled environmental conditions and pool temperatures to minimize external bias (Barbosa et al., 2019).

Data were analyzed using descriptive statistics (mean, standard deviation, minimum–maximum values) followed by Pearson correlation analysis and multiple regression to determine the simultaneous contribution of independent variables to performance. Prior to inferential analysis, data were standardized using a T-Score (50 + 10[(X−M)/SD]) to equalize different units of measurement (Nikolaidis et al., 2018). Normality and multicollinearity tests were performed as prerequisites for regression analysis. Data processing was performed using SPSS version 29 with a significance level of $\alpha = 0.05$ (95% confidence level).

This analytical approach allows for the comprehensive identification of dominant factors influencing 10×50 meter swimming skills, in accordance with the principles of anthropometry–biomotor integration in modern coaching science (Pratama et al., 2024; de Alencar Matos et al., 2025).

RESULTS AND DISCUSSION

Result

Descriptive Analysis

Descriptive analysis was conducted to provide an overview of the body structure profile (X1), physical potential (X2), and 10×50 meter freestyle swimming skills (Y). Summary statistics are presented in Table 1.

Table 1.
Results of Descriptive Analysis of Research Variables (n = 45)

Variable	Mean	SD	Varians	Minimum	Maximum
Body Structure (X1)	297.06	52.07	2712.15	185	399
Physical Potential (X2)	248.62	31.64	1001.51	184	318
10×50 m Front Crawl (Y)	36.07	6.46	41.83	22.15	48.30

Based on Table 1, body structure variables showed significant variation (SD = 52.07), indicating heterogeneity in athletes' anthropometric dimensions. This variability is biomechanically relevant because height, arm length, and chest circumference contribute to stroke length and propulsion efficiency (Morais et al., 2020; De Souza Castro et al., 2023).

Physical potential had an SD of 31.64, reflecting differences in strength, power, and endurance capacity between athletes. The literature indicates that biomotor differences, such as upper extremity strength and VO_2max, significantly influence performance consistency in repeated sprint swimming (Schreven et al., 2022; Zacca et al., 2020).

The mean 10x50-meter time was 36.07 seconds with an SD of 6.46, indicating moderate performance variation. Empirically, time consistency in the 10x50 meter protocol reflects the interaction of anaerobic capacity and aerobic stabilization (Santos et al., 2023).

Normality Test

Before testing the hypotheses, a Shapiro-Wilk normality test was performed to ensure the data distribution met the parametric assumptions ($\alpha = 0.05$). The test results are shown in Table 2.

Table 2.
Results of the Shapiro-Wilk Normality Test

Variable	Statistics	Sig. (p)	Description
Body Structure (X1)	0.972	0.344	Normal
Physical Potential (X2)	0.983	0.742	Normal
10×50 m Front Crawl (Y)	0.980	0.631	Normal

All variables showed $p > 0.05$, indicating a normal distribution of the data. This allowed for the use of Pearson correlation analysis and multiple linear regression. Normal distributions of sports performance variables are commonly found in trained athlete populations (Nikolaidis et al., 2018; Barbosa et al., 2019).

Pearson Correlation Analysis

To test partial relationships between variables, the Pearson correlation test was used. The results are presented in Table 3.

Table 3.
Pearson Correlation Test Results

Variabel	r	Sig. (p)	Interpretation
X1 – Y	0.620	0.001	Strong
X2 – Y	0.845	0.001	Very Strong

The r value of 0.620 ($p < 0.05$) indicates a strong relationship between body structure and 10x50 meter swimming skills. Biomechanically, optimal anthropometric dimensions contribute to increased propulsion efficiency and drag reduction (Toussaint & Truijens, 2018; Geladas et al., 2017).

The r value of 0.845 ($p < 0.05$) indicates a very strong relationship between physical potential and swimming performance. This finding is consistent with research showing that arm strength, power, and cardiorespiratory endurance are the main predictors of middle-distance swimming performance (Schreven et al., 2022; Santos et al., 2023; Zacca et al., 2020).

Multiple Regression Analysis

To determine the simultaneous contribution of body structure and physical potential to performance, a multiple regression analysis was conducted. A summary of the results is presented in Table 4.

Table 4.
Results of Multiple Regression Analysis

Predictor Variables	R	R^2	F	Sig. (p)
X1 & X2 → Y	0.845	0.714	52.298	0.001

The R value of 0.845 indicates a very strong simultaneous correlation. The coefficient of determination R^2 of 0.714 means that 71.4% of the variation in 10×50-meter swimming skills is explained by a combination of body structure and physical potential, while 28.6% is influenced by other factors such as technique, pacing strategy, and psychological factors (Seifert et al., 2018; Crowley et al., 2017).

The F value of 52.298 ($p < 0.05$) indicates a statistically significant regression model. Conceptually, these findings reinforce the integrative biomechanics-physiology theory that swimming performance is the result of a synergy between structural leverage and force production capacity (Pratama et al., 2024; de Alencar Matos et al., 2025).

Therefore, any improvement in an athlete's anthropometric and biomotor profile will be followed by an improvement in 10×50-meter freestyle performance. These results emphasize the importance of an integrated profiling approach in designing evidence-based training programs for swimming athletes in South Sulawesi.

Discussion

The results of this study indicate that body structure and physical potential have a significant relationship and contribute strongly to the 10×50-meter freestyle swimming skills of athletes from South Sulawesi. This finding reinforces the paradigm that swimming performance is the result of a complex interaction between morphological, physiological, and biomechanical factors, not solely technical skill (Morais et al., 2020; Barbosa et al., 2019). With a coefficient of determination of 71.4%, the combination of these two variables explains the majority of the variation in performance, underscoring the importance of an integrated profiling approach in athlete development.

Morphologically, body structure plays a crucial role in determining hydrodynamic efficiency. Height, arm length, and body segment dimensions influence stroke length and propulsion surface area, which directly impact swimming speed (Geladas et al., 2017; Mazzilli, 2019). Recent studies have shown that lean body mass and body composition distribution are associated with swimming kinematic indices such as stroke frequency and stroke efficiency (Sokołowski et al., 2023; Takagi et al., 2023). Athletes with longer body structures tend to generate greater propulsive force with relatively less resistance, thereby increasing their efficiency in the water (Toussaint & Truijens, 2018).

The findings of this study align with those of Wądrzyk et al. (2022), who stated that differences in body composition determine performance in various swimming events, particularly in the context of repeated sprints. In the 10×50 meter protocol, the combination of anaerobic capacity and the ability to maintain technique under fatigue is a key factor (Santos et al., 2023). Therefore, optimal body structure not only supports the start and turn phases but also helps maintain stroke consistency throughout repetitions.

In addition to morphological aspects, physical potential—which includes muscle strength, power, and cardiorespiratory endurance—shows a stronger correlation with performance than body structure alone. This is consistent with research by Schreven et al. (2022), which found that upper extremity strength correlates significantly with sprint speed and propulsive capacity. Alves et al. (2022) and Price et al. (2023) added that core strength and trunk stability play a role in maintaining a streamlined position, thereby reducing drag during the recovery phase.

In the context of the 10x50 meter race, anaerobic endurance and aerobic stabilization are dominant factors. Zacca et al. (2020) explained that repeated sprint swimming requires good lactate buffering capacity and the ability to maintain power output under conditions of accumulated fatigue. A study by De Souza Castro et al. (2023) confirmed that muscle power and lean mass contribute significantly to the start and turn phases, which over repeated short distances can accumulate substantial time gains.

The interaction between body structure and physical potential in this study confirms the integrative model of swimming performance proposed by Morais et al. (2022), where morphological characteristics provide a "leveraging framework," while physiological capacity determines the magnitude of force that can be generated. Athletes with ideal body dimensions but insufficient strength will not achieve optimal speed; conversely, athletes with high strength but inadequate body structure will experience hydrodynamic inefficiency.

This finding is also relevant to research by Dopsaj et al. (2020) and Matos et al. (2022), which showed that increasing specific swimming strength through a resistance training program directly reduced swim time. Karabıyık et al. (2023) and Ruiz-Navarro et al. (2025) emphasized the importance of integrating anthropometric evaluation and physical capacity development into training periodization to achieve sustainable performance.

In the context of regional development, the results of this study have strong practical implications. Training programs in South Sulawesi need to be directed at strengthening biomotor capacity based on individual profiling, taking into account the anthropometric characteristics of each athlete. Xiao et al. (2021) showed that an individualized training approach increases the efficiency of physiological adaptation and accelerates improvements in competitive performance.

Furthermore, regular monitoring of body composition and physical capacity is a crucial element of a coaching system. BOZKURT & GÖRAL (2021) emphasized that periodic evaluation of anthropometric characteristics and physical fitness allows coaches to identify athletes' potential and weaknesses early. This approach aligns with the principles of evidence-based coaching, which emphasize decision-making based on objective data.

Theoretically, the results of this study reinforce the concept of swimming biomechanics that optimal performance is the result of a balance between propulsive force and drag force (Toussaint & Truijens, 2018). Body structure determines leverage potential and body position, while strength and power determine force production capacity. When these two components develop simultaneously through structured training, movement efficiency increases and run times decrease significantly.

However, approximately 28.6% of performance variation is still influenced by other factors such as technique, pacing strategy, and psychological aspects. Seifert et al. (2018) emphasized that intra-limb and inter-limb coordination also play a role in maintaining stroke rhythm. Therefore, technique development remains an integral component of coaching.

Overall, this research makes a significant contribution to the development of swimming coaching in Indonesia. By demonstrating that body structure and physical potential simultaneously significantly influence 10×50-meter swimming skills, this study emphasizes the importance of a multidimensional approach in athlete development. Achieving maximum performance in freestyle swimming relies not only on technical skills but also requires a comprehensive synergy between morphological characteristics and physiological adaptations acquired through a systematic and sustainable training program.

Therefore, it can be concluded that optimizing body structure and physical potential is the main foundation for improving 10×50-meter freestyle swimming skills in South Sulawesi athletes, while also providing the basis for developing science-based coaching strategies to enhance competitiveness at the national and international levels.

CONCLUSION

Based on the results of statistical analysis and conceptual interpretation, it can be concluded that body structure and physical potential are significant determinants of 10×50-meter freestyle swimming skills in South Sulawesi athletes. Partially, body structure, including anthropometric dimensions such as height, arm length, and body composition, is closely related to propulsion efficiency and drag reduction in the water. This finding confirms that morphological characteristics provide biomechanical leverage that supports stroke length and streamline position stability.

Furthermore, physical potential, including muscle strength, power, and cardiorespiratory endurance, showed a stronger relationship to performance, indicating that force production capacity and the ability to maintain repeated intensity are key factors in the 10×50-meter protocol. Simultaneously, body structure and physical potential contributed 71.4% to performance variation, indicating that success in middle-distance swimming is a result of the synergy between morphological characteristics and physiological adaptations.

Therefore, improving athlete performance requires an individual profile-based coaching approach that integrates anthropometric evaluation and biomotor capacity development systematically and continuously.

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